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ANALYSIS AND DESIGN OF STEEL INDUSTRIAL BUILDING

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ABSTRACT:
Steel industrial buildings are preferred for manufacturing plants, warehouses and factory outlets of various industries. These buildings require large column-free space and relatively light-weight roofs, for which roof truss system supported in columns is adopted. Electrically operated Over-head Travelling (EOT) cranes are required for carrying or shifting of heavy goods or containers, which induce moving loads. The structural design of such industrial buildings under action of dead, live, crane and wind loads, such that they are stable and safe, is a challenging task. In this study, a typical one-storied roof-trussed industrial building of 20 m x 50 m (working plan) and of 8 m height, provided with an EOT crane (of 200kN capacity) is analyzed and designed for various load combinations by computer modeling using STAAD. Pro software. Considering dead, live, crane and wind loads as per Indian codes of practice. The analysis and design of gantry girder, crane columns, roof columns, roof truss, purlins, girts, wall & roof bracings and foundations will be carried out manually and / by computer modeling using STAADPro software.
KEYWORDS —1.AutoCAD2. STAAD Pro

1. INTRODUCTION

1.1. History of Industrial Steel Buildings

Early Use of Steel (18th-19th centuries)

Steel began to be used in construction during the Industrial Revolution. Initially, iron was used, but steel's stronger properties soon became apparent. The Bessemer process (developed in the 1850s) allowed for mass production of steel, making it more affordable and widely available.

Late 19th Century

Steel-frame construction emerged, leading to the creation of stronger, taller buildings. The first notable steel-framed building was the Home Insurance Building in Chicago (1885), often considered the first modern skyscraper.

Early 20th Century

Steel became a dominant material in industrial buildings, factories, and warehouses due to its strength, flexibility, and speed of construction. The rise of mass production and the need for larger spaces to accommodate machinery drove this demand.

Late 20th Century to Present

Steel industrial buildings became more efficient and versatile, with advances in design and materials leading to more sustainable and energy efficient structures. The use of steel in large warehouses, distribution centres, and factories continues to dominate due to its durability and cost effectiveness.

1.2. Applications of Industrial SteelBuildings

- Warehouses and Storage Facilities
- Manufacturing Plants
- Distribution Centers
- Agricultural Buildings
- Commercial Buildings
- Aircraft Hangars
- Sports Arenas and Gymnasiums
- Workshops and Garages
- Cold Storage Facilities
- Mining and Oil Industry Structures
- Modular or Prefabricated Buildings

1.3. Advantages of steel industrial building

- Design Flexibility
- Durability and Strength
- Cost-Effectiveness
- Speed of Construction
- Low Maintenance
- Sustainability
- Energy Efficiency

- Adaptability
- Safety
- Pest Resistance

2. STEEL INDUSTRIAL BUILDING SYSTEM

High rise steel buildings account for a very small percentage of the total number of structures that are built around the world. The majority of steel structures being built are low-rise buildings, which are generally of one storey only. Industrial buildings, a subset of low-rise buildings is normally used for steel plants, automobile industries, utility and process industries, thermal power stations, warehouses, assembly plants, stores. Garages, small scale industries, etc. These buildings require large column free areas. Hence interior columns, walls, and partitions are often eliminated or kept to a minimum. Most of these buildings may require adequate head room for the use of an overhead travelling crane. The evolution of structural steel design brought us from the theory that the stiffer the structure the better. Today, flexibility and ductility are the key issues. The days of drafting are almost hone and digitizing the structure in the computer saves time, ensures quality and usually results in a lower cost.

2.1. Components of steel industrial building

Gantry girder:

A gantry girder is a horizontal beam that spans between two supports, typically piers or abutments, and is used to support a moving load, such as a crane or a train. It is usually a steel or concrete beam, and is designed to withstand the weight and movement of the load.

Columns:

Vertical members that form the main support structure, typically made of I- beams or H-sections, and are secured to the foundation

Beams / Rafter:

Horizontal members that span between columns, forming the roof structure and supporting the roof panels.

Truss:

Triangular or latticework structures that provide alternative support for the roof or upper floors, especially for longer spans.

Purlin:

Horizontal members that run perpendicular to the rafters and support the roof panels.

Bracing:

Diagonal or cross-bracing members that provide lateral stability and resist wind or seismic forces.

Eave struts:

Horizontal members that support the eaves (the overhang of the roof).

Bracket:

A bracket refers to a structural element that is attached to a column or beam to support a load.

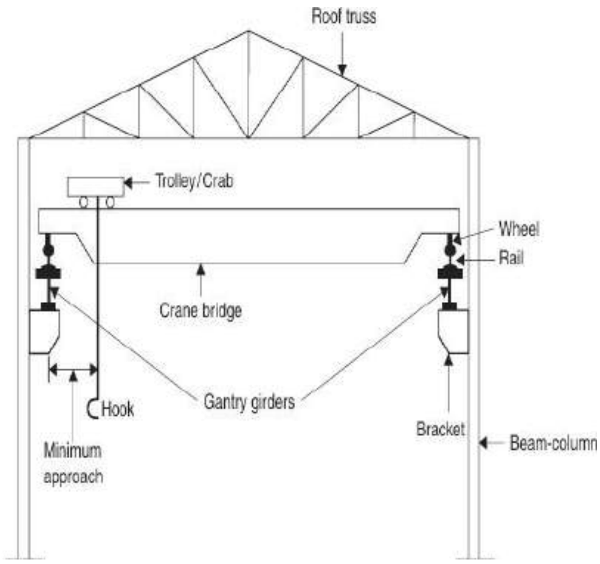


Figure 1. Structural layout

3. LOADS

Dead load

The constant/permanent load applied on the structure at roof level is called dead load. The intensity of load is assumed in accordance with IS 875 (part I)1987

Roof Load

The weight a roof structure must support, including its own weight (Dead Load) IS 875 (Part I):1987 and any temporary loads like snow (Live Load) IS 875 (Part II):1987.

Wind Load

The basic wind speed, design wind speed and design wind pressure are calculated in accordance with IS 875 (Part III): 2015.

Crane load

The intensity of load is assumed in accordance with IS 875 (Part II):1987.

LOAD COMBINATIONS
LOAD COMBINATIONS FOR DESIGN
1) 1.5 DEAD LOAD + 1.5 LIVE LOAD
2) 1.5 DEAD LOAD + 1.5 WIND LOAD
3) 1.5 DEAD LOAD + 1.5 LIVE LOAD +1.05 CRANE LOAD
4) 1.2 DEAD LOAD + 1.2 LIVE LOAD + 0.6 WIND LOAD +1.05 CRANE LOAD
LOAD COMBINATIONS FOR SERVICEABILITY
1) DEAD LOAD + 1.0 LIVE LOAD
2) DEAD LOAD + 1.0 WIND LOAD
3) DEAD LOAD + 1.0 LIVE LOAD +1.0 CRANE LOAD
4) 1.0 DEAD LOAD + 0.8 LIVE LOAD + 0.8 WIND LOAD+ 0.8 CRANE LOAD

TABLE 1. Load combinations

- Total of 92 load cases are generated including combinations

4. ANALYSIS AND DESIGN

4.1.Plan of Building

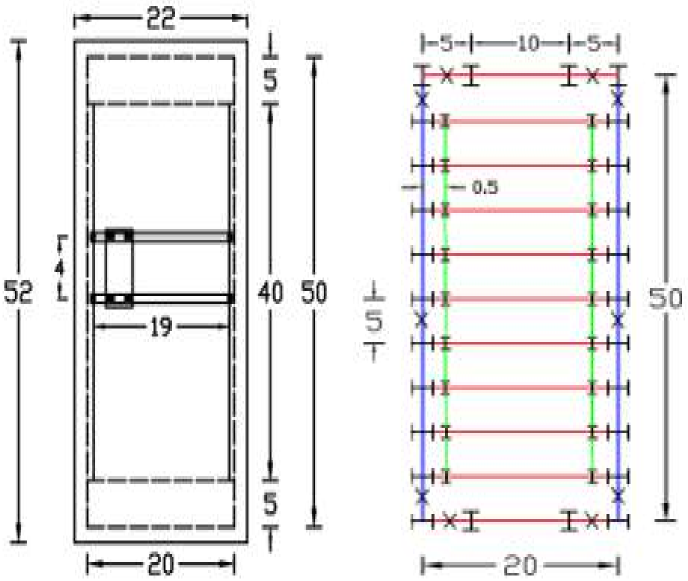


Figure 2. Plan of the building

4.2 Design of Gantry Girder

The design of the gantry girder involves key parameters like crane capacity, self-weight, and load calculations. The analysis of vertical, lateral, and longitudinal loads is crucial in determining the required section properties.

Crane capacity = 150 kN
Weight of crab / Trolley = 40 kN
Wheel base = 3.5m
Self-weight of rail = 300 N/m
Minimum hook approach = 0.8m
Spacing of columns = Length of gantry girder
= 5 m

Vertical load

Figure 3. Crane bridge

Initial Size of Gantry Girder

Plastic section modulus

Required $Z_{pz} = \frac{1.4 Mdz\ \gamma mo}{fy} = \frac{1.4*270.8*(10)6*1.1}{250} = 1668.13 * 10^3 mm^3$

From steel tables select the initial size of Gantry Girder,

NPB500*200*90.68

$A=11500mm^2$ $r_1=21mm$
$t_w=10.2mm$ $D=500mm$ $I_z=48199*10^4 mm^4$ $Z_{ez}=1927.9*10^3 mm^3$
$b_f=200mm$ $I_y=2141*10^4 mm^4$
$Z_{pz}=2194.27*10^3 mm^3$ $t_f=16mm$
$r_y=43.1mm$

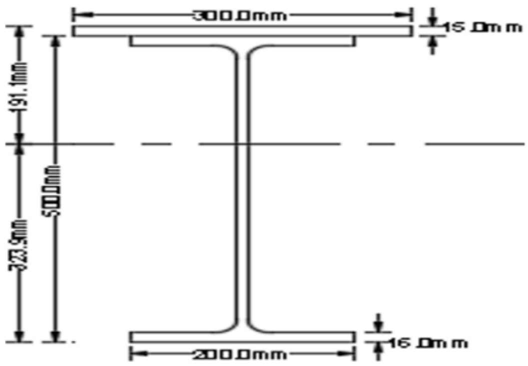


Figure 4. Gantry girdersection (I– section)

Check for shear, web buckling, web crippling and deflection are satisfied. Hence the section is safe.

5. INTERMEDIATEROOFTRUSS

L=20m
Assume corrugate galvanised iron(G.I) sheets
Let pitch = 1/6
End height = 1 m

$\frac{\text{Rise}}{\text{Span}} = \frac{1}{6} \qquad \because \frac{R}{\left(\frac{20}{2}\right)} = \frac{1}{6}$

R = 1.67 mm ≈ 2 m

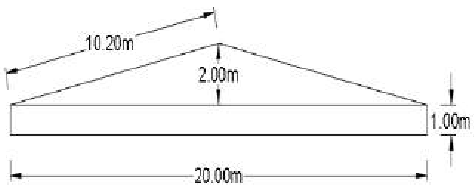


Figure5. Roof truss

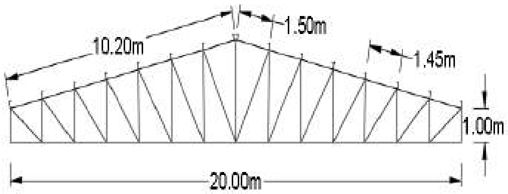


Figure6. Rooftruss with Purlins

No. of purlins = 8(on each rafter)

Spacing of purlins = 10.2/7 = 1.46 m

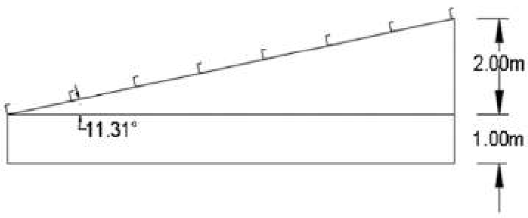
∴provide 7 purlins at 1.45 m at 1 purlin at 1.5 m

$\alpha = \tan^{-1}\left(\frac{2}{10}\right) = 11.31°$

Figure7. Truss withanangle 11.31°

5.1 Intermediate Purlins

Plastic section modulus



$Z_{pzreq} = \frac{M\gamma_{mo}}{f_y} = \frac{1.3*14.36*10^6*1.1}{250}$

SelectISMC200 @ 22.3 kg/m

A = 2850 mm^2D= 200 mm

b_f=75 mm t_w = 6.2 mm

t_f= 11.4 mm I_z = 1830*10^4 mm^4

I_y = 141*10^4 mm^4 r_z = 80.2 mm

r_y = 22.2 mm Z_{ez}=181*10^3 mm^3

$$Z_{pz}=211.25*10^{3}\ mm^{3}$$

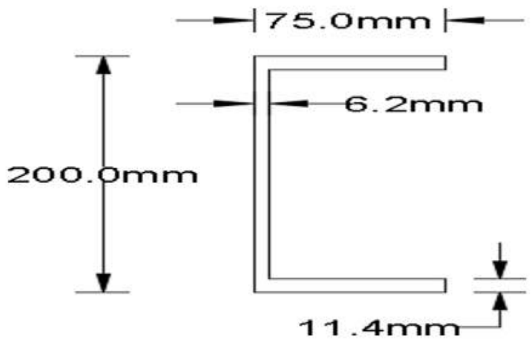


Figure8. ChannelSection

Check for shear and deflection are satisfied. Hence the section safe.

5.2 Designofbottom chord:

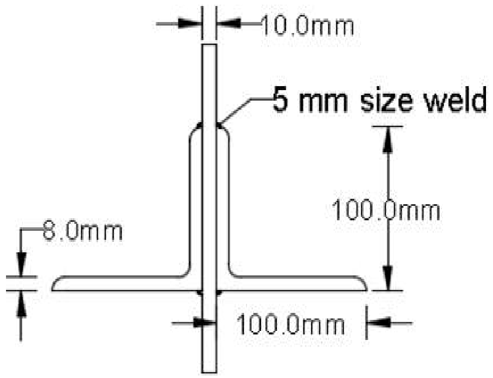


Figure 9.BottomChord

The end connections are done by welding 2∟100×100×8
Gusset thickness = 10mm
Weld size = 5mm

5.3 Design ofangles

2 ∟70 70 × 8 connected to both sides of gusset

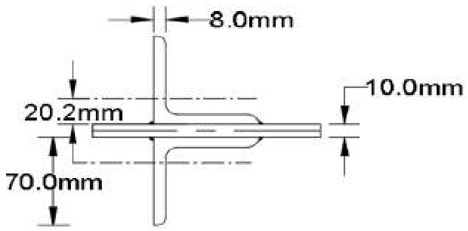


Figure10. AngleDesign

6. DESIGN OFBEAM–COLUMN

6.1CriticalloadcombinationofBeam-Column:

Critical load combination for section: 89

PT= 88.26 kN

M=258 kN-m

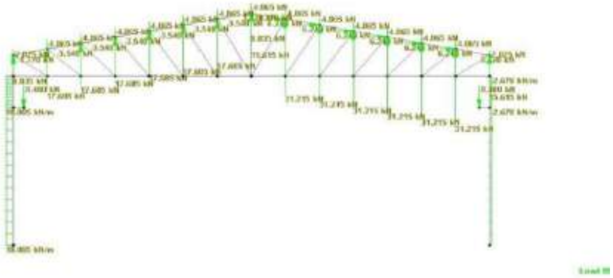


Figure 11. Criticalloadcombinationfor section89

DISPLACEMENT DIAGRAM

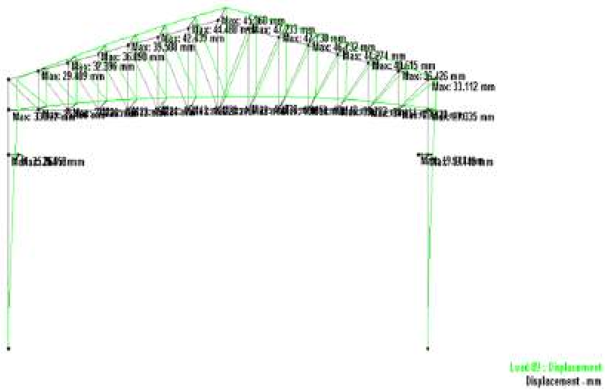


Figure12. Displacementdiagram

Maximumdisplacement=47.738mm

SHEARFORCE DIAGRAM

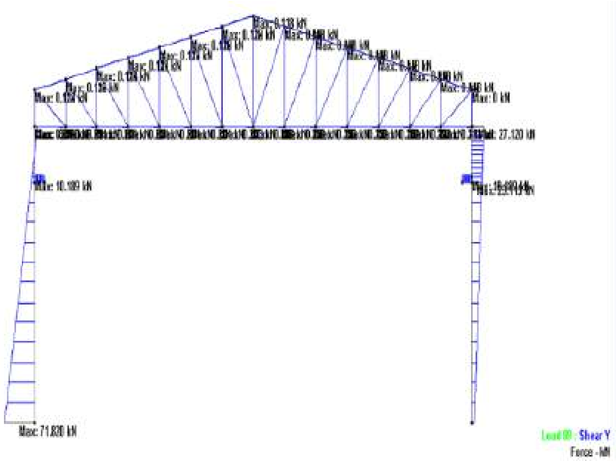


Figure13. Shearforce diagram

Maximum shearforce =71.82kN

BENDINGMOMENT DIAGRAM

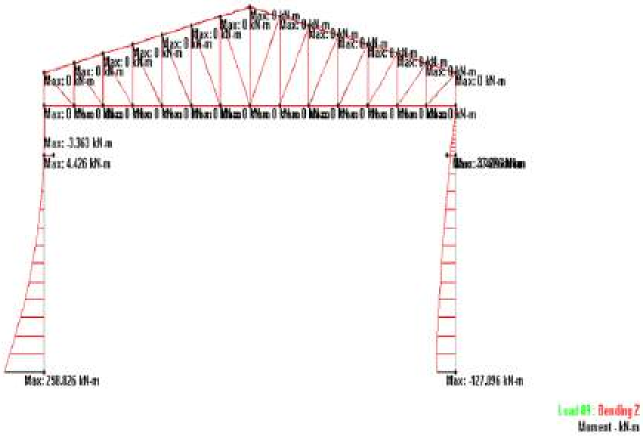


Figure14. Bendingmoment diagram

Maximumbending moment=258.826kN–m

6.2 Design of Beams
NPB 500*200*107.31

A = 13670 mm bf = 202 mm
t_w = 12 mm D = 506 mm
t_f = 19 mm R = 21 mm
I_{zz} = 57777 cm^4 I_{yy} = 2621.7 cm^4
r_{zz} = 205.6 mm r_{yy} = 43.8 mm
Z_{ez} = 2283.7 cm^3 Z_{pz} = 2613.13 cm^3
Check for shear is satisfied. Hence the section is safe.

6.3 Loadcombination for column:

Loadcombinationforsection:16
P_c=448.66 kN
M_z@ top = 131.40 kN-m
M_z@bottom=92.17kN-m
Let f_{cd}= 120 Mpa
The required area of the section

$$=\frac{2*448.66*10^3}{120} = 7477.66 mm^2$$

ConsiderISHB300 @58.8 Kg/m

A =7480 mm^2 I_{ZZ}=12600*$10^4$$mm^4$
t_f=10.6 mmD =300 mm
I_{YY}=2200*$10^4$$mm^4$ Z_{ez}=836*$10^3$$mm^3$
b_f= 250mm r_Z= 130 mm
Z_{pz}=921.68*$10^3$$mm^3$ t_W= 7.6 mm
r_y= 54.1 mm

Check for Yielding and Buckling are satisfied. Hence the section is safe.

7.BRACKETDESIGN

7.1Design forbracketplates:

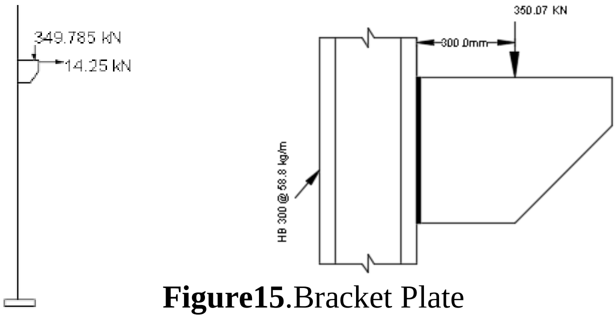


Figure15.Bracket Plate

P_y=233.19 kNP_X=9.5 kN
F_y= 250 MPa
f_u=410MPa
Provide two bracket plates
The thickness of bracketplate=12mm
Toconnect12mmthick bracket, therequired size of the filletweldis 10mm.

8.CONCLUSION

In this project study, analysis and design of roof trussed steel industrial building with gantry girder was carried out by useof STAADProsoftware. Thebuilding working plan was 20 m x 50m. The design of gantrygirder was done considering the effect of moving loads. Anintermediate frame (alongwithrooftruss) was modelled and analysed fordead,live,craneandwindloadinaccordancewithIS875 –PartsI,IIandIII. Also,theframewas analysed forallpossibleloadcombinations(92loadcombinations)inaccordancewithIS 800-2007. Initially, the design was done using STAAD Pro and later the adequacy was checked through manual calculations. In totality, the analysis and design of purlins, roof truss members, beam-columns andbracketconnectionweredone.Thetotalweightofanintermediateframewas3.1MetricTonsapproximatelyi. e. 30.89 kN.

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